ELSEVIER

Trends in Reproductive, Smoking, and other Chronic Disease Risk Factors by Birth Cohort and Race in a Large Occupational Study Population

D. MICHAL FREEDMAN, PHD, ROBERT E. TARONE, PHD, MICHELE M. DOODY, MS, APARNA MOHAN, MD, BRUCE H. ALEXANDER, PHD, JOHN D. BOICE, PHD, AND MARTHA S. LINET, MD

PURPOSE: To illustrate the value of cohort studies to assess trends in chronic disease risk factors.
METHODS: In collaboration with the American Registry of Radiologic Technologists and the University of Minnesota, the National Cancer Institute initiated a cohort study of cancer among radiologic technologists. More than 90,000 technologists who responded to a mailed questionnaire were grouped into ten birth cohorts from before 1920 through 1960 and later, and stratified by self-reported racial/ethnic groups. Trends in height, smoking, and reproductive factors were analyzed.
RESULTS: Among the trends observed were that the proportion of young men (< 18 years) smoking generally fell in each birth cohort after 1925, whereas the proportion of young women smoking rose for those born after 1950. Among women born since 1940, the mean age at menarche for white women has remained at 12.5 years, but has declined among black and Asian/Pacific Islander women. Recent birth cohorts (since 1955) show among the highest mean ages at birth of first child (> 26 years), highest rates of nulliparity at age 25 (≥ 63 %), and lowest mean parity levels (≤ 1.7) compared with earlier cohorts.
CONCLUSION: Analyses of large cohorts can clarify birth cohort trends in chronic disease risk factors.
Ann Epidemiol 2002;12:363–369.

KEY WORDS: Chronic Disease, Neoplasms, Risk Factors, Trends, Menarche, Body Height, Smoking, Oral Contraceptives, Reproduction, Parity.

INTRODUCTION

Knowledge of historic trends in risk factors for cancer, heart disease, and other chronic diseases can inform our understanding of historic disease patterns and help us anticipate future disease burdens. Large cohort studies that span several birth periods, such as the cohort of radiologic technologists reported here, provide a valuable resource for exploring these trends. This study uses the questionnaire responses of more than 90,000 radiologic technologists who were born across more than a forty-year time span to describe trends in chronic disease risk factors, and to examine differences and similarities in these trends among self-reported white, black, and Asian/Pacific Islander birth cohorts.

From the Division of Cancer Epidemiology and Genetics, National Cancer Institute, Bethesda, MD (D.M.F., R.E.T., M.M.D., A.M., J.D.B., M.S.L.); and University of Minnesota, Minneapolis, MN (B.H.A.).

Address reprint requests to: D. Michal Freedman, Ph.D., M.P.H., Division of Cancer Epidemiology and Genetics, National Cancer Institute, EPS Room 7087, 6120 Executive Boulevard, Bethesda, MD 20892–7238.

Tables of all mean, proportion, and standard deviations for data presented in the following figures are available from the corresponding author.

Received March 28, 2001; revised September 17, 2001; accepted September 26, 2001.

METHODS

Study Population

In collaboration with the American Registry of Radiologic Technologists (ARRT) and the University of Minnesota School of Public Health, the National Cancer Institute (NCI) initiated a study to evaluate health outcomes associated with long-term occupational exposure to radiation and other risk factors among ARRT registrants. Details of the study are reported elsewhere (1, 2).

In brief, the original study population consisted of 146,022 radiologic technologists who had been certified by the ARRT for at least two years between 1926 and 1982 and resided in the U.S. Beginning in 1984, a baseline questionnaire was mailed to living technologists with a current address (N = 132,519) and 90,305 responses were received. A follow-up questionnaire, which largely serves as the basis for this current analysis, was mailed to 125,707 living technologists with a current address between 1995 and 1998, regardless of whether they had responded to the first questionnaire; 91,173 responses were received to the second questionnaire.

Questionnaire

A 16-page questionnaire asked subjects about established and suspected risk factors for cancer, including demographic characteristics, physical characteristics, smoking,

655 Avenue of the Americas, New York, NY 10010

1047-2797/02/$–see front matter
PII S1047-2797(01)00295-2

AEP Vol. 12, No. 6
August 2002: 363–369

Selected Abbreviations and Acronyms

ARRT 5 American Registry of Radiologic Technologists
NCI 5 National Cancer Institute
in. 5 inches

other lifestyle behaviors, and reproductive factors, as well as radiation-related medical and occupational histories.

Statistical Methods

We grouped respondents into ten mostly five-year birth cohorts (< 1920, 1920–24, 1925–29, 1930–34, 1935–39, 1940–44, 1945–49, 1950–54, 1955–59, and ⩾ 1960). We explored changes over time in the height of men and women, an anthropometric variable, which has been linked to cancer (3–9) and heart disease (10, 11). We also examined trends in smoking behavior (proportion of cohort ever-smoking (⩾ 100 cigarettes in lifetime), proportion smoking before age 18, mean age at start of smoking) in men and women because smoking is a major cause of cancer, heart disease, chronic obstructive pulmonary disease, and other illnesses (12). In addition, we examined trends in reproductive factors, which have been associated with cancer and other chronic diseases (13–19). These included mean age at menarche, mean age of women at birth of first child, proportion of women in each birth cohort who were nulliparous at age 25 years, mean number of live births, and indicators of oral contraceptive use (proportion of cohort ever-using, proportion using ⩾ 5 years, mean age began using).

We specifically excluded cohort members who were nuns from our analysis of trends in smoking, nulliparity, parity, and oral contraceptive use, because nuns comprised about 6% (66/1106 women) of the female radiologic technologists who were born before 1920 and they had reproductive and other lifestyle experiences that did not reflect the wider population of women. We looked at birth cohort trends stratified by self-reported race/ethnic group (white, black, Asian/Pacific Islander), as identified by the participants. We did not examine trends in other racial/ethnic groupings, which included too few participants.

RESULTS

The respondent study population of radiologic technologists is more than three-fourths women and predominantly white (Table 1). The majority was born between 1940–59 (78%) and most were married. As shown in Figures 1a and 1b, mean heights rose over time for male and female technologists among all racial groups. In each birth cohort, mean heights did not differ substantially between whites and blacks, while mean heights of Asian/Pacific Islanders were lower.

TABLE 1. Demographic characteristics of radiologic technologists who responded to a mail questionnaire, 1995–1998

Characteristic	No.	%
Sex		
Male	20974	23
Female	69998	77
Race		
White	84202	93
Black	2840	3
Asian/Pacific islanders	2523	3
Other	1195	1
Unknown	212	<1
Birth year		
<1920	1677	2
1920–29	4733	5
1930–39	12520	14
1940–49	30359	33
1950–59	40958	45
1960+	724	1
Unknown	1	<1
Marital status		
Married	69825	77
Widowed	3170	4
Divorced/separated	10904	12
Never married	6293	7
Unknown	780	<1
Education[a]		
⩽12 years or radiation tech. vocational	48526	55
College or graduate school	36425	40
Other	4718	5
Unknown	636	<1
Residence[a]		
Northeastern	17349	19
Southern	16715	18
Midwestern	21941	24
Western	12180	13
Unknown	22787	25

[a]Derived from the earlier baseline questionnaire.

Figures 2a through 4b provide three indicators of smoking behavior among men and women. Among white and black men, the proportion ever-smoking was nearly 70% in the birth cohorts of the late 1920s and early 1930s, before declining to about 38% and 32%, whites and blacks, respectively, in the late 1950s (Figure 2a). The proportion of Asian/Pacific Islanders who smoked was markedly lower in each successive birth cohort. The proportion smoking before age 18 (high school age) also reached a high of 33% (white), 26% (black), and 22% (Asian/Pacific Islander) in the birth cohorts of the late 1920s/early 1930s, and a low of 16% (white), 7% (black), and 9% (Asian/Pacific Islander) in the birth cohort of 1955–59 (Figure 3a). The mean age men began smoking, however, has been relatively constant for white men, but more erratic for the other racial/ethnic groups (Figure 4a). The proportion of black men and Asian/Pacific Islander smoking before age 18 has been consistently lower than for white men, with the mean age at which they began smoking consistently higher.

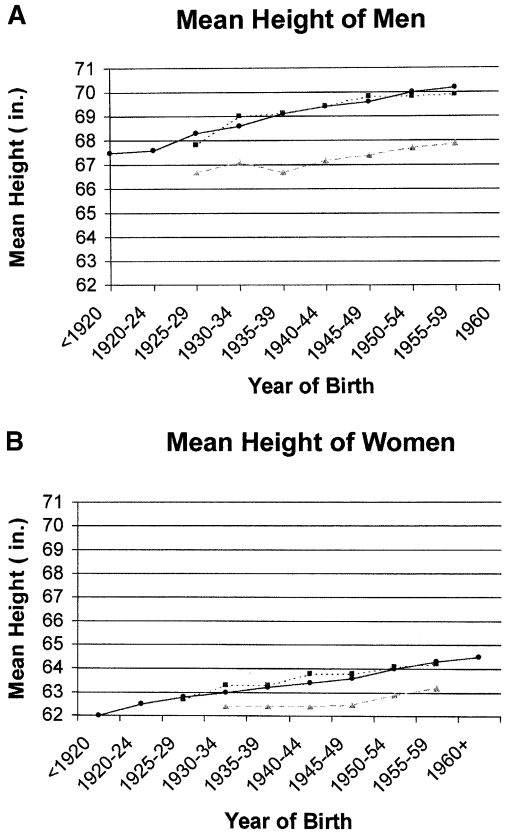

FIGURE 1. The figure does not include data for any group where fewer than 50 individuals comprised the birth cohort. ● White, ■ Black, ▲ Asian/Pacific Islander.

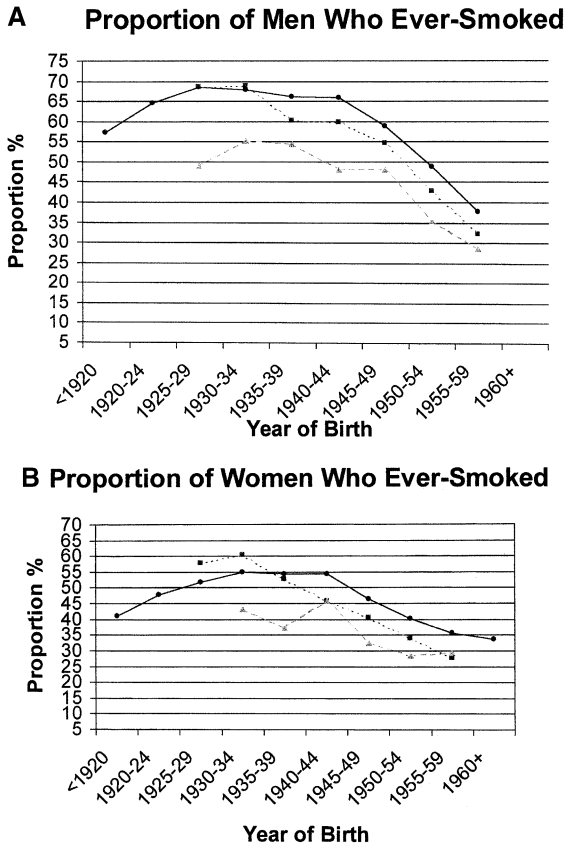

FIGURE 2. The figure does not include data for any group where fewer than 50 individuals comprised the birth cohort. The figure excludes women who were nuns. The number excluded by birth cohort were as follows <1920, 66; 1920–24, 35; 1925–29, 30; 1930–34, 34; 1935–39, 29; 1940–44, 9; 1945–49, 6; 1950–54, 2; 1955–59, 1; 1960 +, 0. ● White, ■ Black, ▲ Asian/Pacific Islander.

Compared to men, a smaller proportion of women have smoked in each birth cohort, but the trends by year of birth and racial/ethnic group were similar to those of men. The proportion of white and black ever-smokers rose to a peak in the birth cohort of the early 1930s, and subsequently fell to levels of 34% and 28% respectively in the birth cohorts of the late 1950s and 1960s (Figure 2b). The proportion of Asian/Pacific Islander women ever-smoking has been lower than white and black women for most birth cohorts. The proportion of women smoking before age 18 has been erratic, but steadily increased among those women born since the 1950s (Figure 3b). In cohorts born after World War II, the proportion of high-school age black women who smoked has been about 60% of that of white women, whereas the proportion of Asian/Pacific Islander women has approached that of white women in the most recent birth cohort. Finally, the mean age that women began smoking fell among white and Asian/Pacific Islander, but not black, women (Figure 4b).

The remaining trends relate to reproductive factors in women. The mean age at menarche of white women fell from 13.1 among those born before 1920 to 12.5 among those born in the early 1940s (Figure 5), and has remained unchanged in subsequent birth cohorts. While the mean age at menarche of black and Asian/Pacific Islander women was similar to white women in early birth cohorts, it has continued to fall, reaching a low of 12.1 among those born in the late 1950s.

The mean age of women at the birth of their first child rose among cohorts born since the early 1940s, reaching a high of about age 27 in the birth cohort of the late 1950s (Figure 6). The mean age at birth of their first child was higher among Asian/Pacific Islander women than the other racial/ethnic groups in each birth cohort, steadily rising for birth cohorts of 1940–44 and later. The proportion of women who were nulliparous at age 25 rose from a low of 39% (white), 44% (black), and 50% (Asian/Pacific Islander) among the cohorts born in the late 1930s and early 1940s to a peak of 69%, 65%, and 75%, respectively among those born in the late 1950s (Figure 7).

Similarly, the mean number of live births among white and black women reached a peak among those born in the early 1930s and declined thereafter, with the mean number

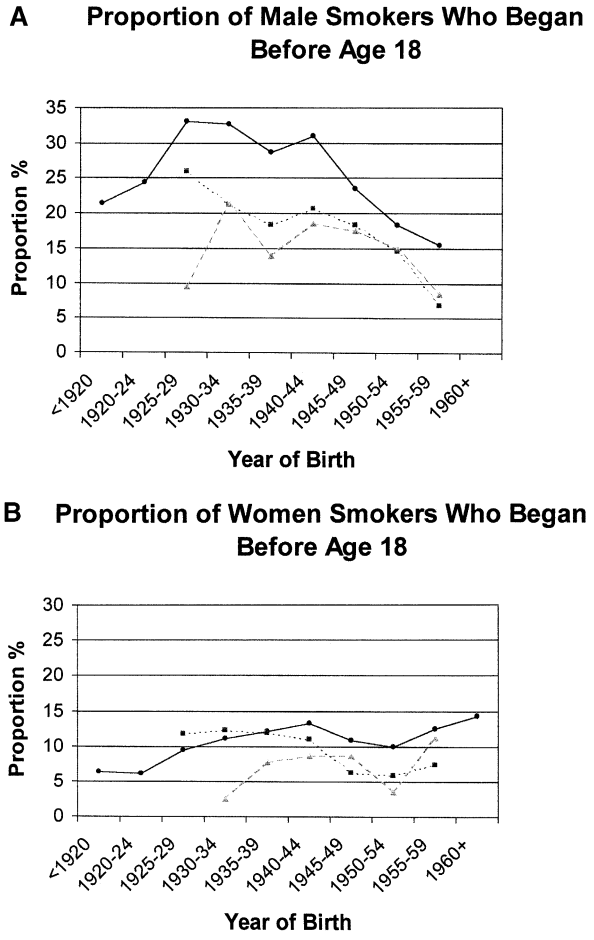

FIGURE 3. The cut-point of age 18 reflects smoking prior to completion of secondary school education. The figure does not include data for any group where fewer than 50 individuals comprised the birth cohort. The figure excludes women who were nuns. ● White, ■ Black, ▲ Asian/Pacific Islander.

of births generally lower among black than white women in this cohort (Figure 8). In contrast, Asian/Pacific Islander women reached a peak live birth rate in the early 1940s before subsequently declining.

The proportion of white and black women ever using oral contraceptives has remained above 70% among those born since the 1940s, and reached a high of roughly 80+ percent among the latest birth cohorts, with black rates slightly exceeding those of whites and Asian/Pacific Islanders (Figure 9a). The proportion of users with duration of use $\geq$ 5 years has exceeded 39% for all cohorts born in the early 1930s or later and reached a high of 61% among white women born since 1960, 69% among black women born in the late 1950s, and 54% among Asian/Pacific Islander women born in the early 1950s (Figure 9b). Correspondingly, the mean age that women began using oral contraceptives has fallen to a low of less than 20 years in the youngest birth cohorts (Figure 9c).

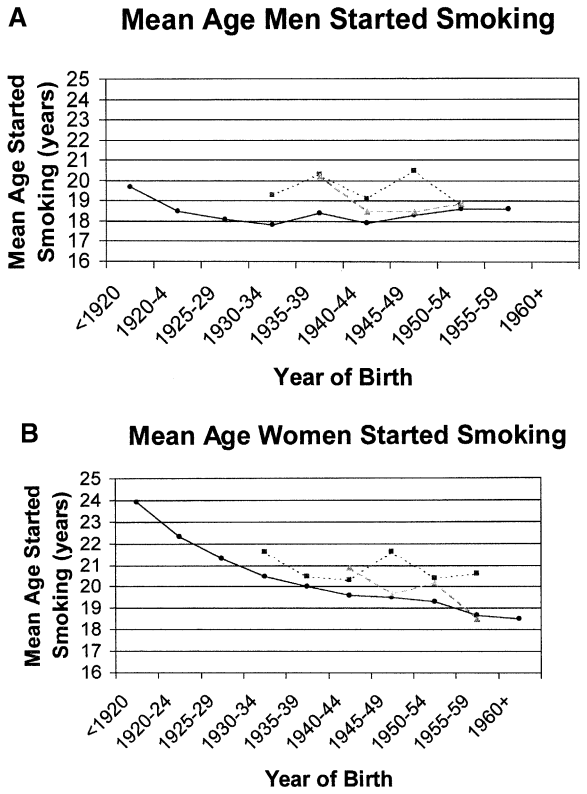

FIGURE 4. The figure does not include data for any group where fewer than 50 individuals comprised the birth cohort. The figure excludes women who were nuns. ● White, ■ Black, ▲ Asian/Pacific Islander.

DISCUSSION

Few studies have evaluated trends in important risk factors for cancer and other chronic diseases among birth cohorts from different historical periods. None to our knowledge have looked at trends by racial or ethnic group. Some studies have looked at trends in *disease* incidence by birth cohort (20), but these can be difficult to interpret without information on corresponding risk factor patterns. Thus, understanding birth cohort trends in risk factors for chronic disease may be helpful in explaining existing disease trends, as well as in anticipating future changes.

To a great extent the trends in risk factors by birth cohort examined here are parallel for the three groups, with the absolute levels among factors sometimes varying by race/ethnic group, such as for example, with the proportion of ever-smokers. One intriguing birth cohort difference among the racial/ethnic groups is the continuing decline among black and Asian/Pacific Islander women in the age at the onset of menarche, while the mean age of menarche plateaued in whites in the birth cohorts of 1940–44 and later. This finding would be particularly worth assessing in other cohorts because it raises important questions about whether and how hormonal and dietary exposures might differ among racial/ethnic groups.

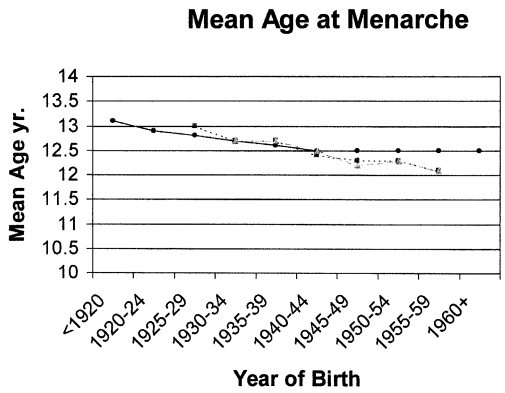

FIGURE 5. The figure does not include data for any group where fewer than 50 individuals comprised the birth cohort. ● White, ■ Black, ▲ Asian/Pacific Islander.

Some trends in risk factors common to the three groups illustrate the potential value of examining trends by birth cohort. For example, declining ovarian cancer rates appear to reflect, at least in part, historical changes in oral contraceptive use. Ovarian cancer incidence and mortality rates have declined among women under age 60 years during the period 1970–95 (21). The marked increase in the use of oral contraceptives for women born since the 1940s, together with the continued reduction in the mean age at first use, may contribute to a continued reduction in ovarian cancer rates in the future (21, 22). With regard to tobacco, the generally declining percentage of men who have ever smoked among succeeding cohorts born since the early 1940s suggests that there may also be a decline in the future societal burden of tobacco-related diseases among men who are currently under the age of 50 years. The increase in the proportion of women smoking before age 18 years among those born since the early 1950s suggests a possible increase in female lung cancer rates in this group. Moreover, changes in smoking behavior may be useful in explaining disease rate changes as they become apparent, such as the recently noted

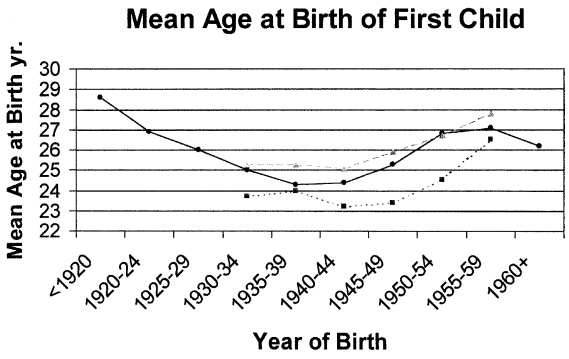

FIGURE 6. The figure does not include data for any group where fewer than 50 individuals comprised the birth cohort. ● White, ■ Black, ▲ Asian/Pacific Islander.

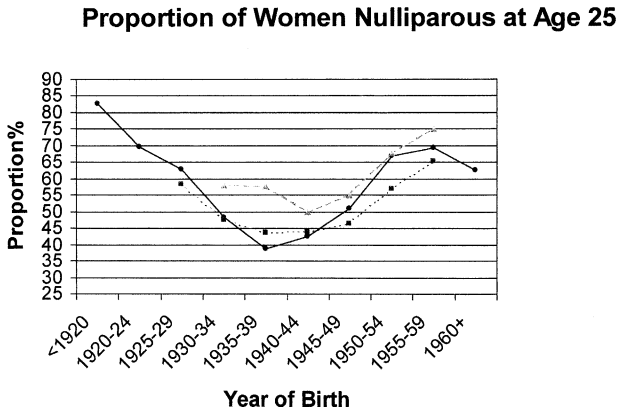

FIGURE 7. The figure excludes women who were nuns. The cut point of age 25 is consistent with definitions of nulliparity used in relation to breast cancer risk. The figure does not include data for any group where fewer than 50 individuals comprised the birth cohort. ● White, ■ Black, ▲ Asian/Pacific Islander.

decline in the rate of decrease of lung cancer mortality rates among those born around 1950 (23).

Trends in breast cancer risk factors observed in the present study are contrary to the declining birth cohort risk of breast cancer mortality observed for women born after 1948 in the U.S. (20). The increase in age at first birth, the continued increase in height, and the stable or declining age at menarche for women born after 1950 are not consistent with decreasing breast cancer mortality in these birth cohorts (20). The magnitude of some breast cancer risk factors, however, may vary with menopausal status, and the reported birth cohort cancer trend reflects almost exclusively premenopausal women because of the young age distribution of our study population. Thus, the trends in breast cancer risk factors observed here raise an important question:

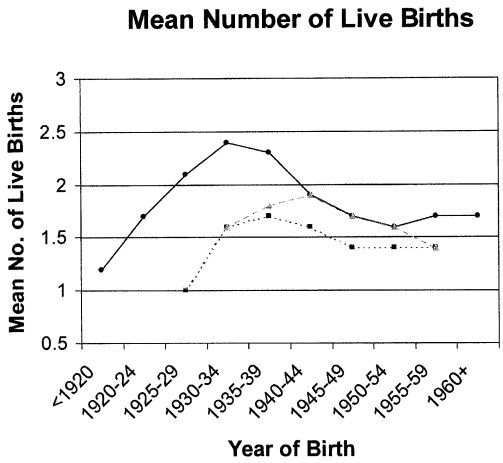

FIGURE 8. The figure excludes women who were nuns. The figure does not include data for any group where fewer than 50 individuals comprised the birth cohort. ● White, ■ Black, ▲ Asian/Pacific Islander.

AEP Vol. 12, No. 6
August 2002: 363–369

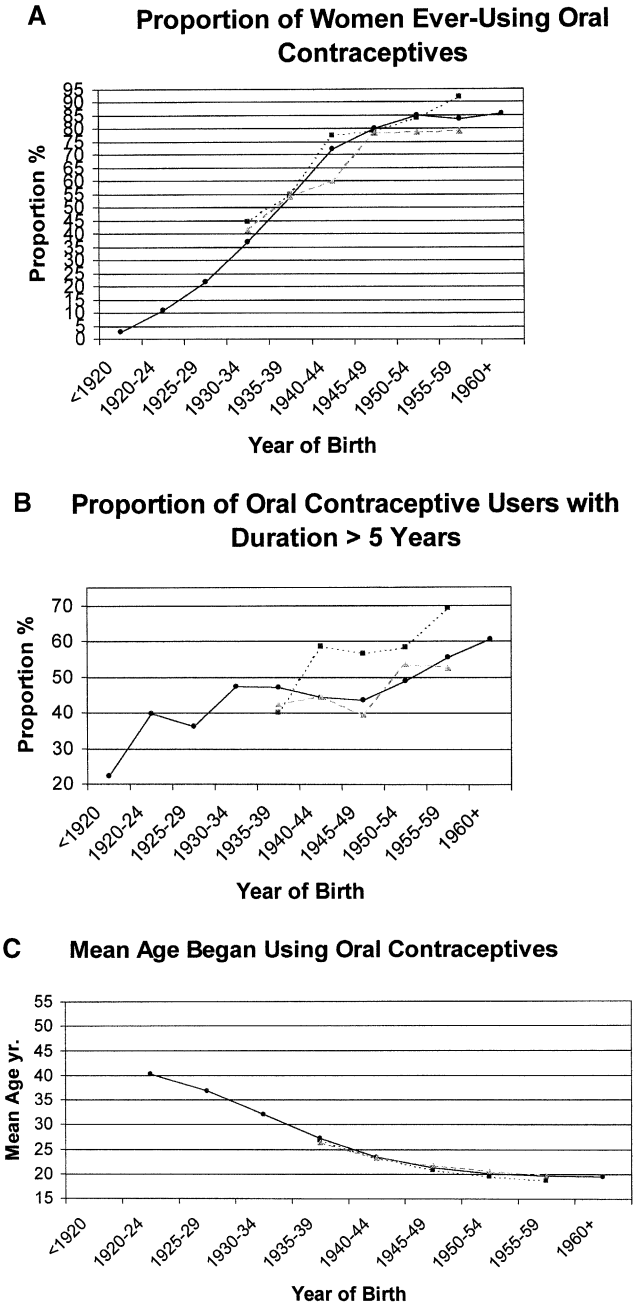

FIGURE 9. The figure excludes women who were nuns. The figure does not include data for any group where fewer than 50 individuals comprised the birth cohort. The mean ages are limited to those who answered the 1st and 2nd questionnaires. ● White, ■ Black, ▲ Asian/Pacific Islander.

whether future cancer rates of those born after 1950 will reflect the declining birth cohort cancer trend that has been observed or whether, as the women in our study population enter menopause, their cancer rates will increase, reflecting the adverse trends in breast cancer risk factors observed among the women of this investigation.

One limitation of the study is its reliance on self-reported information. The accuracy of self-reported fundamental personal information (on height, age at menarche, parity, cigarette smoking) is likely to be high, particularly for events that are important to the individual, such as number of live births and to remain high, even after recall periods of several years (24). Some risk factor information examined here involved memories about the timing of events, such as the age respondent initiated smoking and duration of oral contraceptive use, which would seem more difficult to recall accurately. Nonetheless, one German study indicated reasonably good recall of oral contraceptive histories, including duration of use, number of episodes of use, and time since first and last use (25). Moreover, the respondents appear reasonably consistent on at least one fundamental question, demonstrating a correlation of 0.83 for responses to two questionnaires completed about a decade apart on age at menarche.

Another potential limitation is the representativeness of this cohort of the general U.S. population. The female respondents reflect a group of women who have trained for a career, although many have not been working all of their adult life. The least representative of the broader public are probably the earliest birth cohorts, whose career orientation may explain the high proportion of women who never married (> 20 percent among those born before 1920, excluding nuns). Assessing the representativeness of trends observed in our study population, however, is made difficult by the absence of published literature on birth cohort trends in risk factors among representative cohorts. Although we were able to examine some risk factor trends, such as ever-smoking status, in the cohort of NHANES I and II respondents, some risk factors, such as use of oral contraceptives, were not apparently available in public cohorts. Preliminary analyses of NHANES data suggest similar trends in ever-smoking status among respondents; though, as we suggest, more comprehensive assessment of this and other cohorts is recommended.

However representative of the general population, this cohort of radiologic technologists provides valuable information on changing risks in workers, particularly working women. Moreover, despite its apparent unrepresentativeness on gender and race, it may nonetheless be useful in understanding the general population. We have presented trends by race and gender, which facilitates applying the results to other populations. In addition, the cohort seems to reflect generally the educational attainment of the U.S. population, which has < 45% with one or more years of college compared to about 40% in this cohort (26).

Moreover, working status would appear unimportant to some factors, such as age at menarche and height, and other studies that have examined time trends for these risk factors have reported consistent results. For example, a recent review of secular changes in height noted that in Western and industrialized countries increases in adult height have

varied between 0.3 and 3.0 cm per decade (27), a rate consistent with our findings for the birth cohorts of radiologic technologists. While several reports from Northern European countries indicate a leveling off in the mean age at menarche at about 13 years (28–30), at least one U.S. report (31) documents that, among white mothers of singletons, the mean age of menarche bottomed out at 12.5, the same age we found to characterize menarche for white women born after 1940 in this study.

This is one of the first studies to examine trends in several reproductive and other chronic disease risk factors by birth cohort over several decades among a large population distributed across the U.S., and to examine trends by race. While this analysis of a cohort of working men and women may not be fully representative of the general U.S. population, it conveys some sense of changes in risk factors among workers and presents a model that may be applied to other cohort studies. Similar analyses of other large cohorts may further clarify birth cohort trends in some fundamental risk factors for the major chronic diseases confronting the American population, and thus taken together, such studies can help provide a more complete understanding of changing disease patterns.

This research was supported in part by contracts NO1-CP-15673, NO1-CP-51016, NO2-CP-81005, and NO2-CP-81121 by the National Cancer Institute, National Institutes of Health, and U.S. Public Health Service. The authors gratefully acknowledge the thoughtful comments of Susan Devesa of the National Cancer Institute. We also thank Jerry Reid of the American Registry of Radiologic Technologists for continued support for this research effort, and Diane Kampa of the University of Minnesota for coordination of data collection.

REFERENCES

1. Boice JD, Mandel JS, Doody MM, Yoder RC, McGowan R. A health survey of radiologic technologists. Cancer. 1992;69:587–598.
2. Doody MM, Mandel JS, Lubin JH, Boice JD Jr. Mortality among United States radiologic technologists, 1926–90. Cancer Causes Control. 1998;9:67–75.
3. Albanes D, Taylor PR. International differences in body height and weight and their relationship to cancer incidence. Nutr Cancer. 1990;14:69–77.
4. Gunnell DJ, Smith GD, Holly JMP, Frankel S. Leg length and risk of cancer in the Boyd Orr cohort. BMJ. 1998;317:1350–1351.
5. Tretli S, Robsahm TE. Height, weight and cancer of the oesophagus and stomach: A follow-up study in Norway. Eur J Cancer Prev. 1999;8:115–122.
6. Robsahm TE, Tretli S. Height, weight and gastrointestinal cancer: A follow-up study in Norway. Eur J Cancer Prev. 1999;8:105–113.
7. Swanson CA, Jones DY, Schatzkin A, Brinton LS, Ziegler RG. Breast cancer risk assessed by anthropometry in the NHANES I Epidemiologic Follow-up study. Cancer Res. 1988;48:5363–5367.
8. Swanson CA, Brinton LA, Taylor PR, Licitra LM, Ziegler RG, Schairer C. Body size and breast cancer risk assessed in women participating in the Breast Cancer Detection Demonstration Project. Am J Epidemiol. 1989;130:1133–1141.
9. Giovannucci E, Rimm EB, Stampfer MJ, Colditz GA, Willett W. Height, body weight, and risk of prostate cancer. Cancer Epidemiol Biomarkers Prev. 1997;6:557–563.
10. Wamala SP, Mittleman MA, Horsten M, Schenck-Gustafsson K, Orth-Gomer K. Short stature and prognosis of coronary heart disease in women. J Int Med. 1999;245:557–563.
11. Parker DR, Lapane KL, Lasater TM, Carleton RA. Short stature and cardiovascular disease among men and women from two southeastern New England communities. Int J Epidemiol. 1998;27:970–975.
12. Burns DM, Garfinkel L, Samet JM, eds. Changes in Cigarette-Related Disease Risks and Their Implication for Prevention and Control. Bethesda, MD: National Institutes of Health; 1997.
13. Schairer C. Hormones. In: Harras A, Edwards B, Blot WJ, Ries LAG, eds. Cancer Rates and Risks. Bethesda, MD: National Institutes of Health; 1996:83–86.
14. La Vecchia C, Franceschi S. Oral contraceptives and ovarian cancer. Eur J Cancer Prev. 1999;8:297–304.
15. Weiderpass E, Adami HO, Baron JA, Magnusson C, Lindgren A, Persson I. Use of oral contraceptives and endometrial cancer risk. Cancer Causes Control. 1999;10:277–284.
16. Berkey CS, Frazier AL, Gardner JD, Colditz GA. Adolescence and breast carcinoma risk. Cancer. 1999;85:2400–2409.
17. Petridou E, Syrigou E, Toupakaki N, Zavitsanos X, Willett W, Trichopoulos D. Determinants of age at menarche as early life predictors of breast cancer risk. Int J Cancer. 1996;68:193–198.
18. de Kleijn MJ, van der Schouw YT, van der Graf Y. Reproductive history and cardiovascular disease risk in postmenopausal women: A review of the literature. Maturitas. 1999;33:7–36.
19. Moen MH, Schei B. Epidemiology of endometriosis in a Norwegian county. Acta Obstet Gynecol Scand. 1997;76:559–562.
20. Tarone RE, Chu KC. Evaluation of birth cohort patterns in population disease rates. Am J Epidemiol. 1996;143:85–91.
21. Gnagy S, Ming EE, Devesa SS, Hartge P, Whittemore AS. Declining ovarian cancer rates in U.S. women: Relation to parity and oral contraceptive use. Epidemiology. 2000;11:102–105.
22. Oriel KA, Hartenbach EM, Remington PL. Trends in United States in ovarian cancer mortality, 1979–1995. Obstet Gynecol. 1999;93: 30–33.
23. Jemal A, Chu KC, Tarone RE. Recent trends in lung cancer mortality in the United States. J Natl Cancer Inst. 2001;93:277–283.
24. Olson JE, Shu XO, Ross, JA, Pendergrass T, Robison LL. Medical record validation of maternally reported birth characteristics and pregnancy-related events: A report from the Children's Cancer Group. Am J Epidemiol. 1997;145:58–67.
25. Nischan P, Ebeling K, Thomas DB, Hirsch U. Comparison of recalled and validated oral contraceptive histories. Am J Epidemiol. 1993; 138:697–703.
26. U.S. Census Bureau. Educational Attainment in the United States (Update). Washington, D.C.: U.S. Department of Commence; 2000.
27. Hauspie RC, Vercauteren M, Susanne C. Secular changes in growth and maturation: An update. Acta Paediatr Suppl. 1997; 423:20–27.
28. Vercauteren M, Susanne C. The secular trend of height and menarche in Belgium. Eur J Pediatr. 1985;144:306–309.
29. Helm P, Grolund L. A halt in the secular trend towards earlier menarche in Denmark. Acta Obstet Gynecol Scand. 1998;77:198–200.
30. Liestol K, Rosenberg M. Height, weight and menarcheal age of school girls in Oslo — an update. Ann Human Biol. 1995;22:199–205.
31. Wyshak G. Secular changes in age at menarche in a sample of U.S. women. Ann Human Biol. 1983;10:75–77.